Program for evaluation of rad-hard electronics and mitigation of radiation related problems

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The problem

1. Component Feature Sizes becoming small - 65 nm or less, some now reaching sub 20 nm

2. Increase in sensitivity to single event effects. Even atmospheric neutrons are becoming a problem

3. HEP has unique background. It has common points to other applications but has to deal with different particle composition, cryogenics operation, etc.

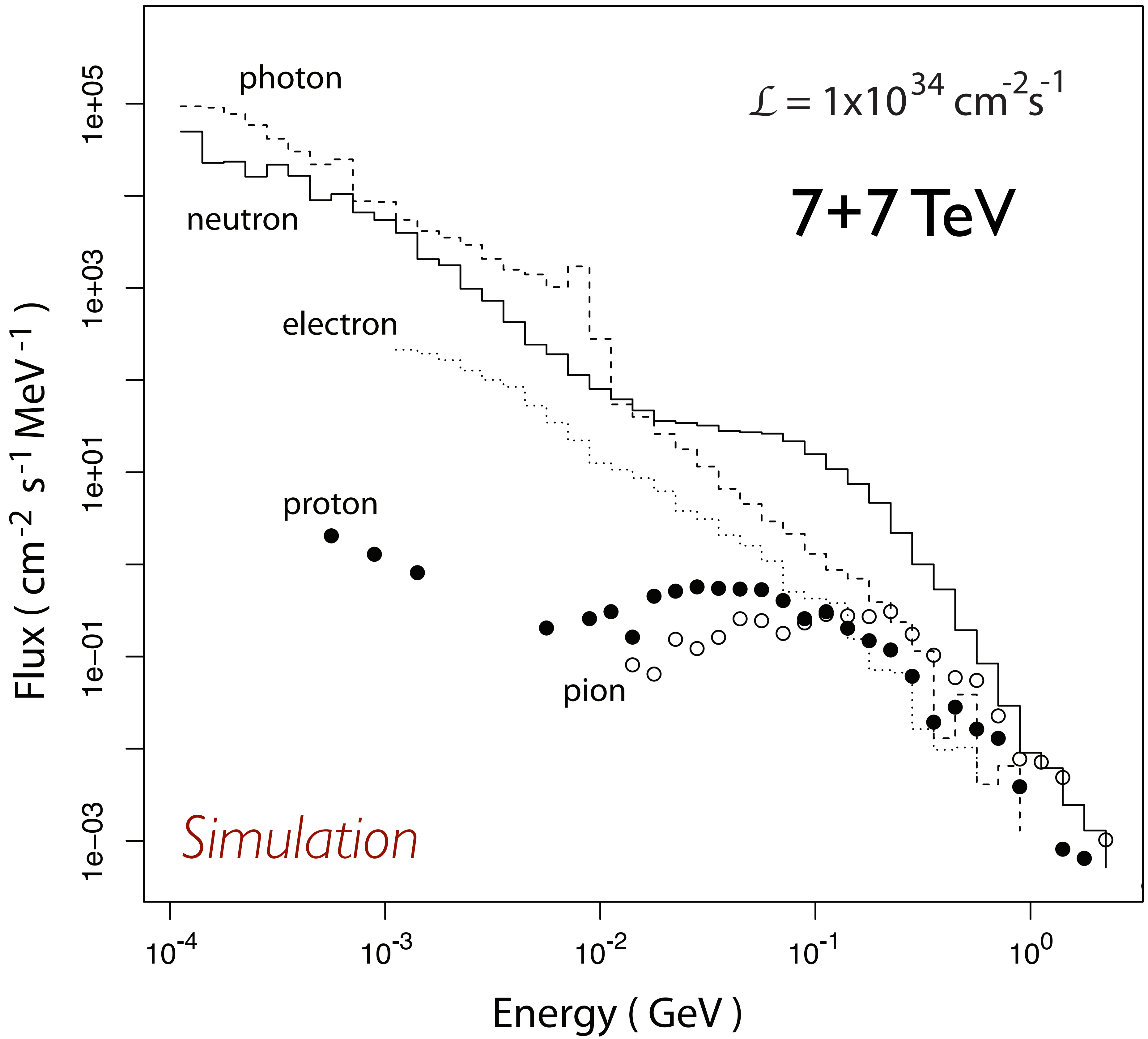
4. We also use a lot of the same components, but not enough to (sometimes) justify production - using COTS would be nice.

Upset is a mechanism induced by a nuclear reaction that happens inside the ASIC

In newer chips there is data that show that even dE/dx can cause upset

Most are not fatal, but produce spurious data or prevent future operations

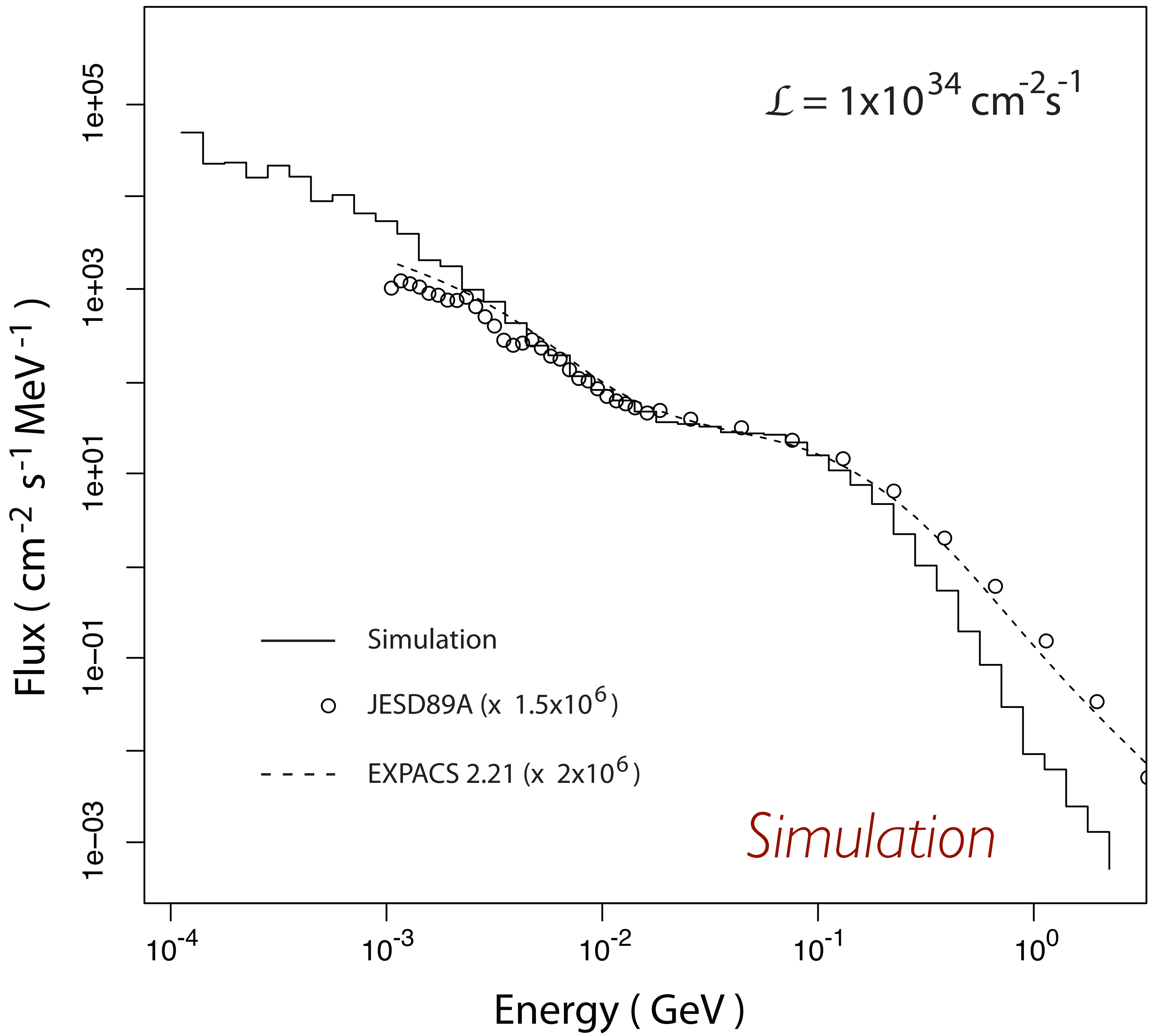
Power devices, on the other hand, can suffer from fatal upsets - gate rupture, burnout.



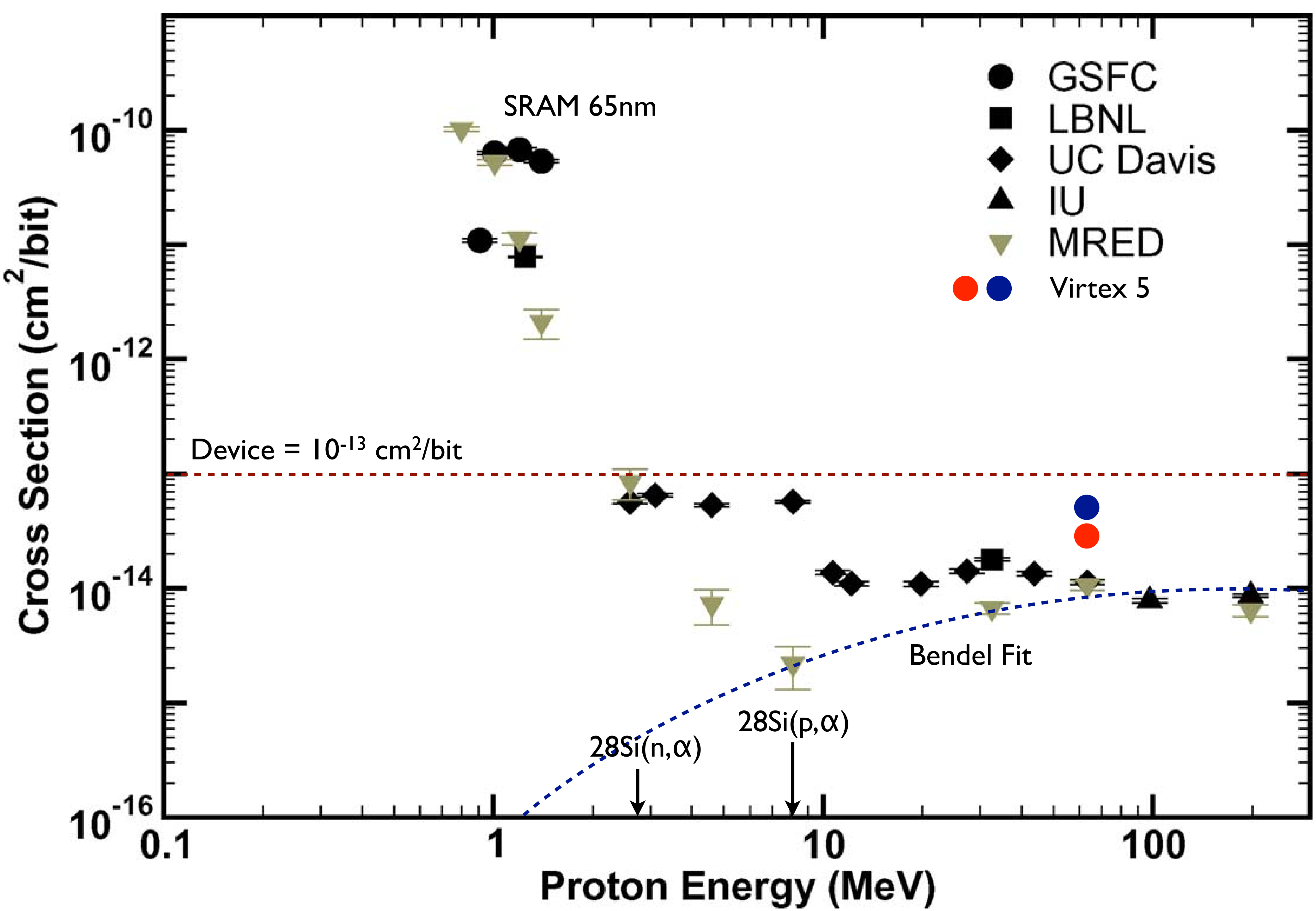
Simulated Particle Energy Spectra for Barrel. Endcap electronics radiation field is ~1/10 Barrel.

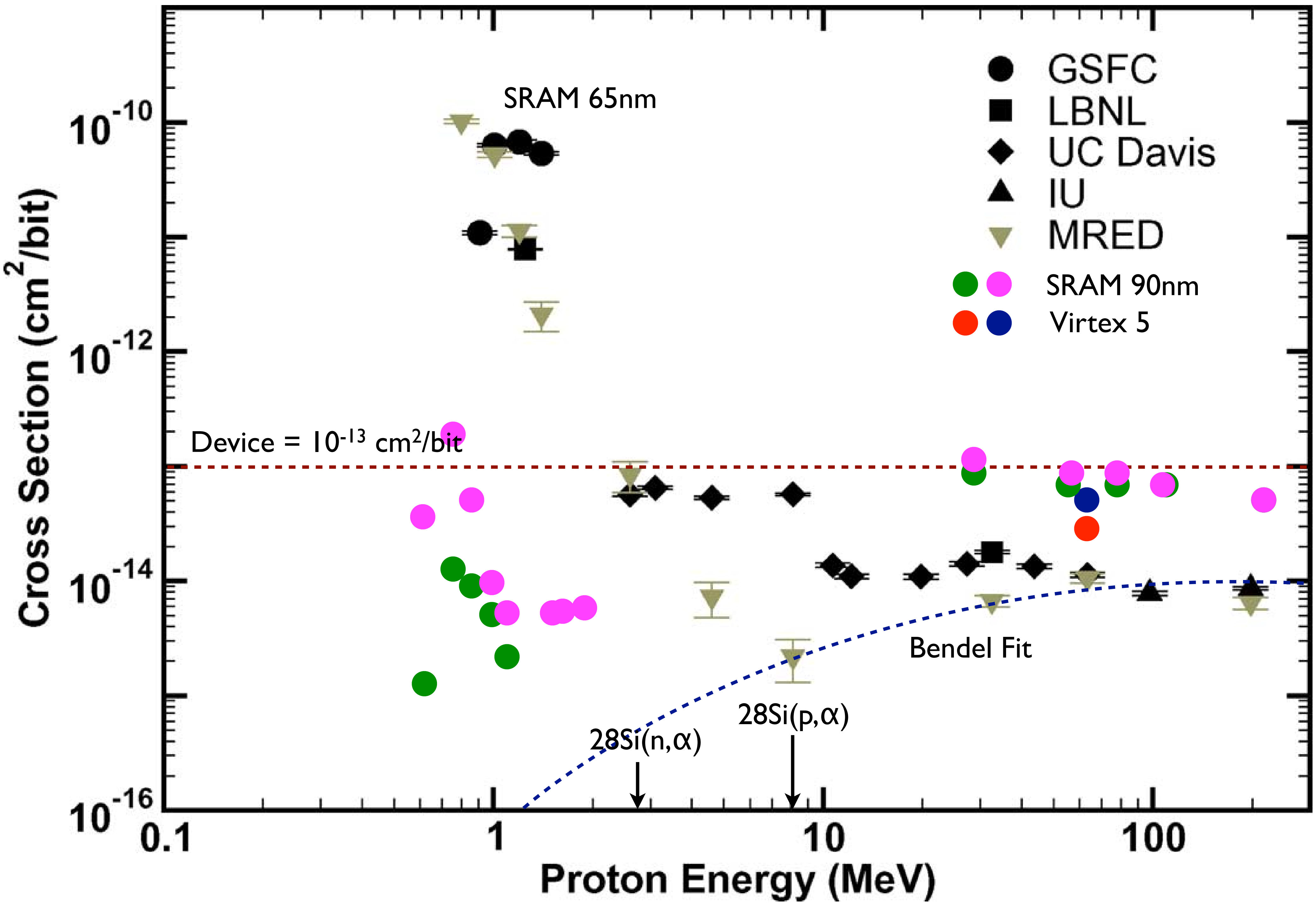
Particle	Threshold (MeV)	Old Simulation (cm^{-2})	New Simulation (cm^{-2})
photon	0.100	4.45×10^{12}	4.08×10^{12}
	10		1.41×10^{11}
neutron	0.100	1.83×10^{12}	1.90×10^{12}
	10		3.52×10^{11}
	21	3.51×10^{11}	2.90×10^{11}
$(e^+ + e^-)$	0.100	6.99×10^{10}	7.60×10^{10}
	10		2.36×10^{10}
$(\pi^+ + \pi^-)$	10		1.04×10^{10}
	21	1.16×10^{10}	1.03×10^{10}
proton	10		8.00×10^{10}
	21	8.02×10^{9}	7.63×10^{9}
$(\mu^+ + \mu^-)$	all		3.5×10^{7}

For 1000 fb^{-1} (approximately 10 years)

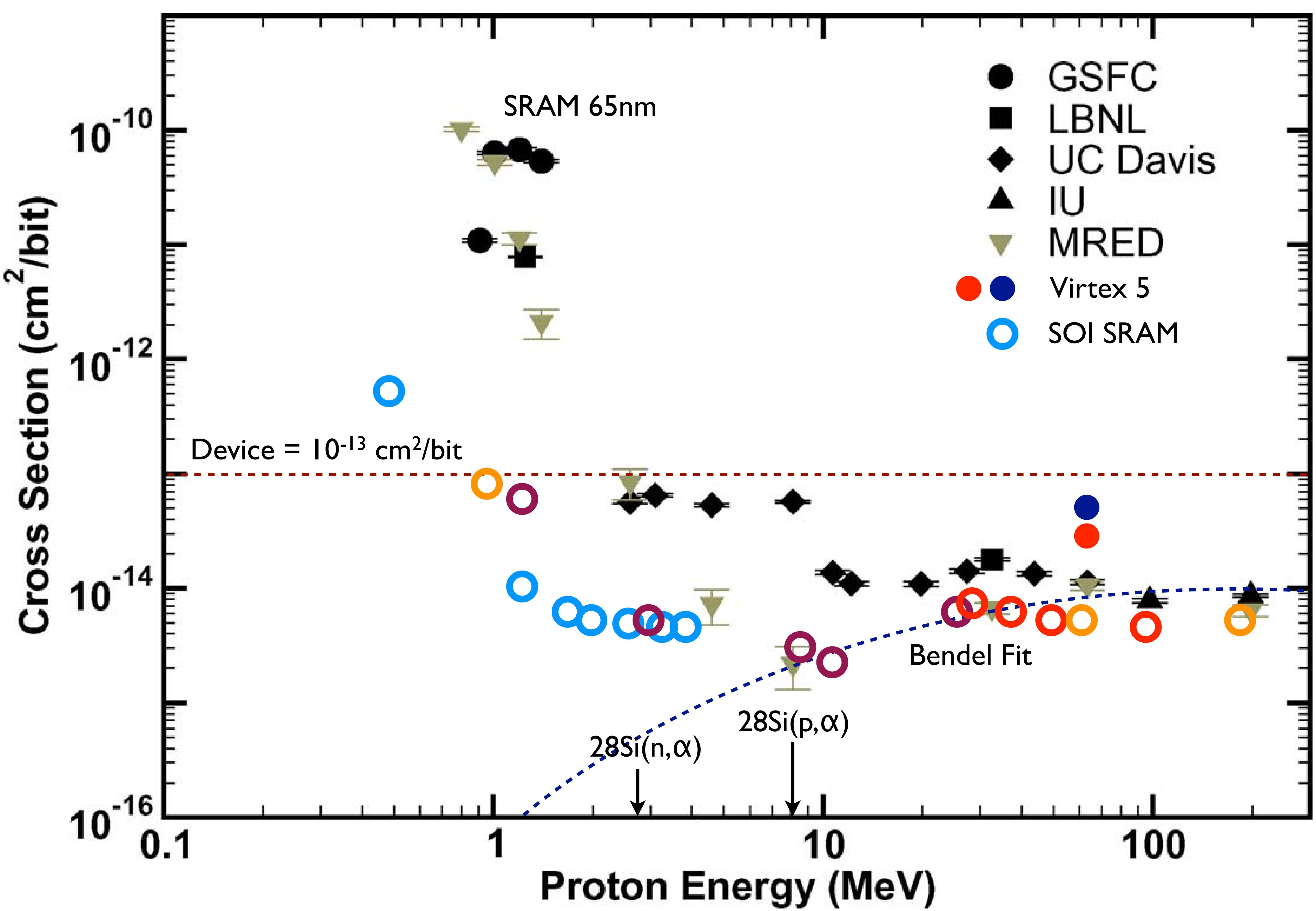


Neutron Spectrum compared to JEDEC and EXPACS

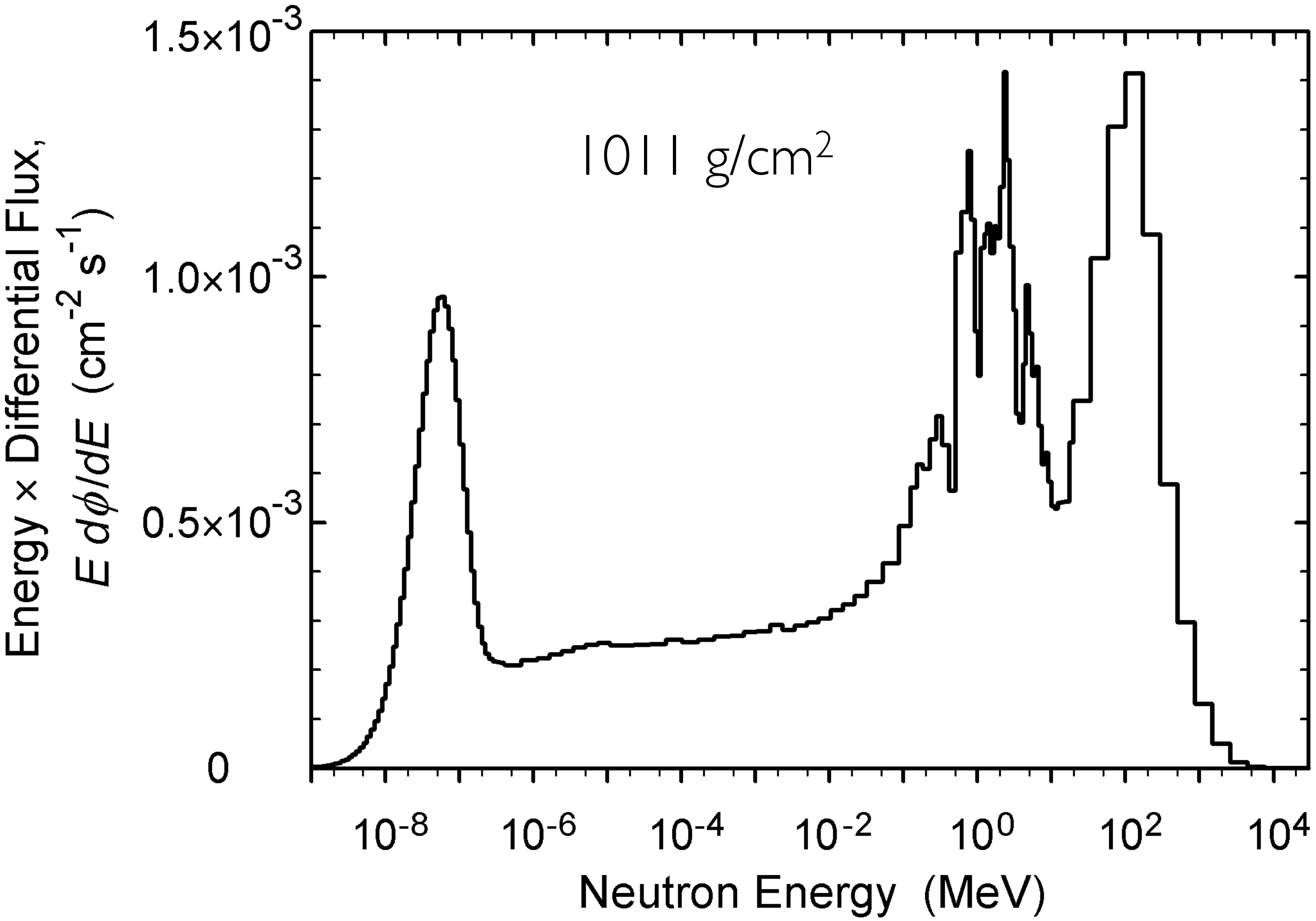

SRAM 65nm
GSFC
LBNL
UC Davis
IU
MRED
Virtex 5
Device = 10-13 cm2/bit
Bendel Fit
28Si(n,α)
28Si(p,α)
Cross Section (cm2/bit)
Proton Energy (MeV)
10-10
10-12
10-14
10-16
0.1
1
10
100



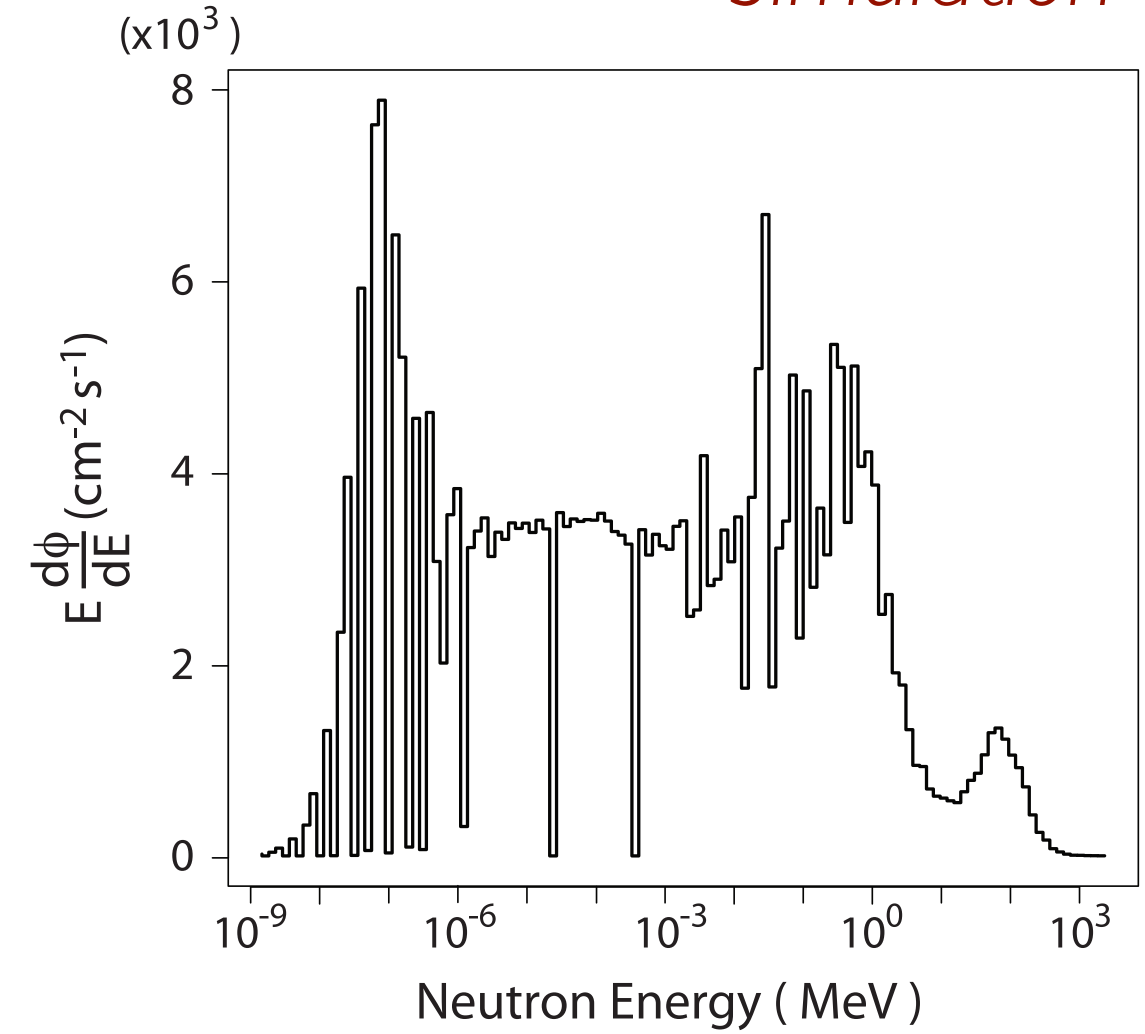
65 vs 90 nm SRAM



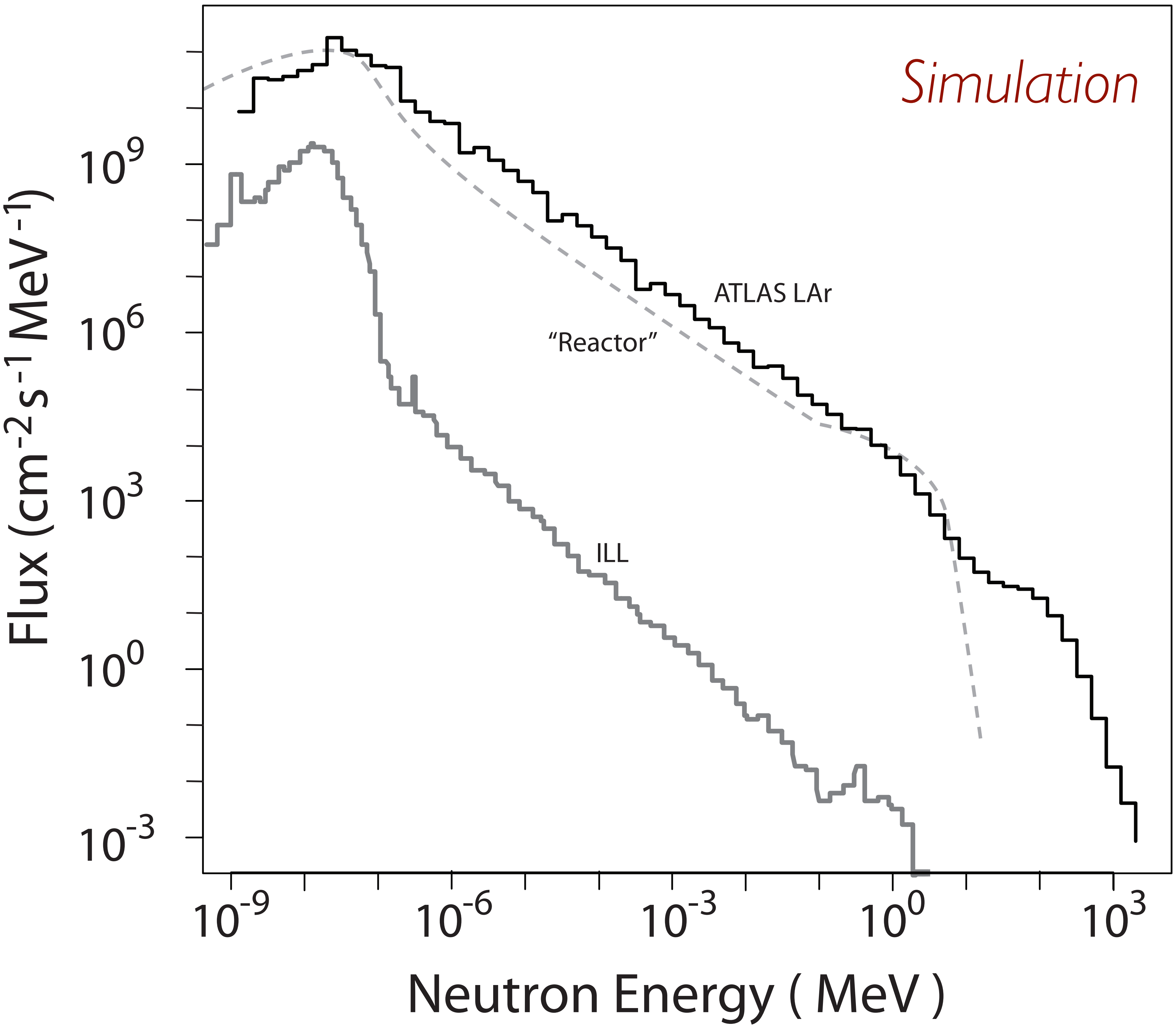
65 nm SOI vs Bulk



Simulation



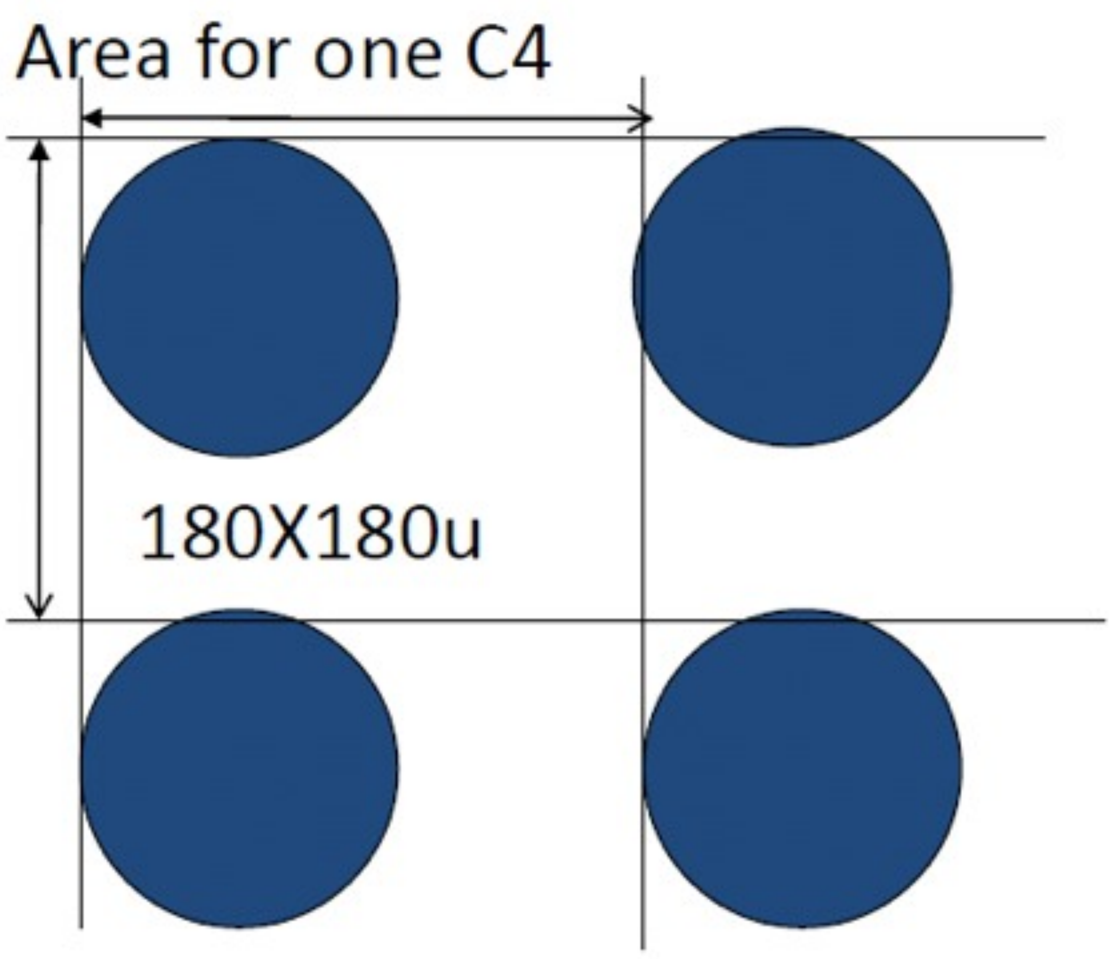
M. S. Gordon, P. Goldhagen, K. P. Rodbell, T. H. Zabel, H. H. K. Tang, J. M. Clem, and P. Bailey , ***Measurement of the Flux and Energy Spectrum of Cosmic-Ray Induced Neutrons on the Ground***, IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOL. 51, NO. 6, DECEMBER 2004

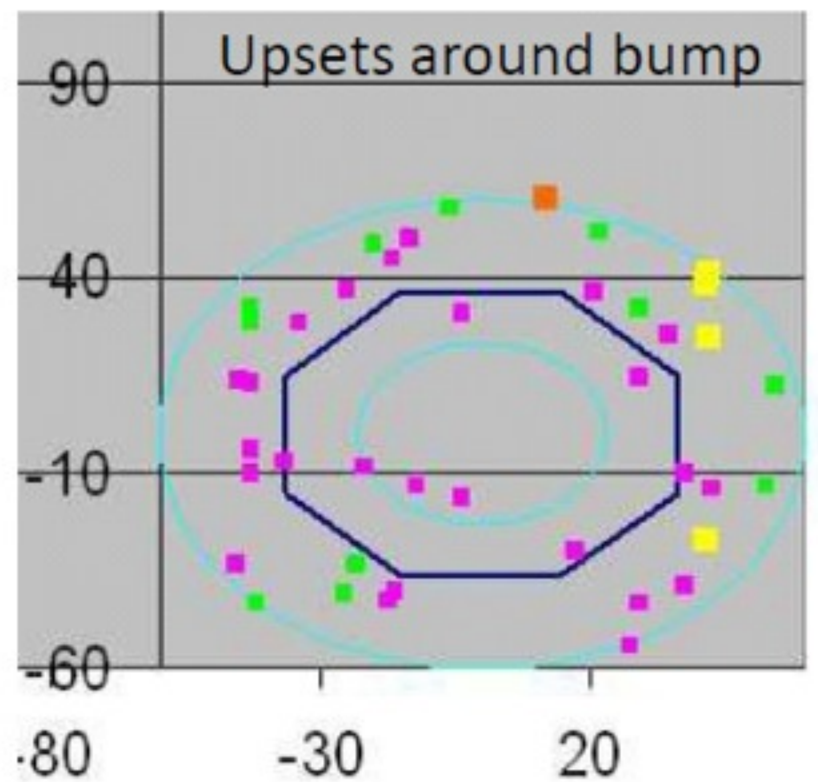


Marcos Olmos, Rémi Gaillard, Andreas Van Overberghe, Jérôme Beaucour, Shijie Wen, Sung Chung, ***Investigation of Thermal Neutron Induced Soft Error Rates in Commercial SRAMS with 0.35 μm to 90 nm Technologies***, Reliability Physics Symposium Proceedings, 2006, IEEE International, p 212

Alpha Particle Upsets from Bumps

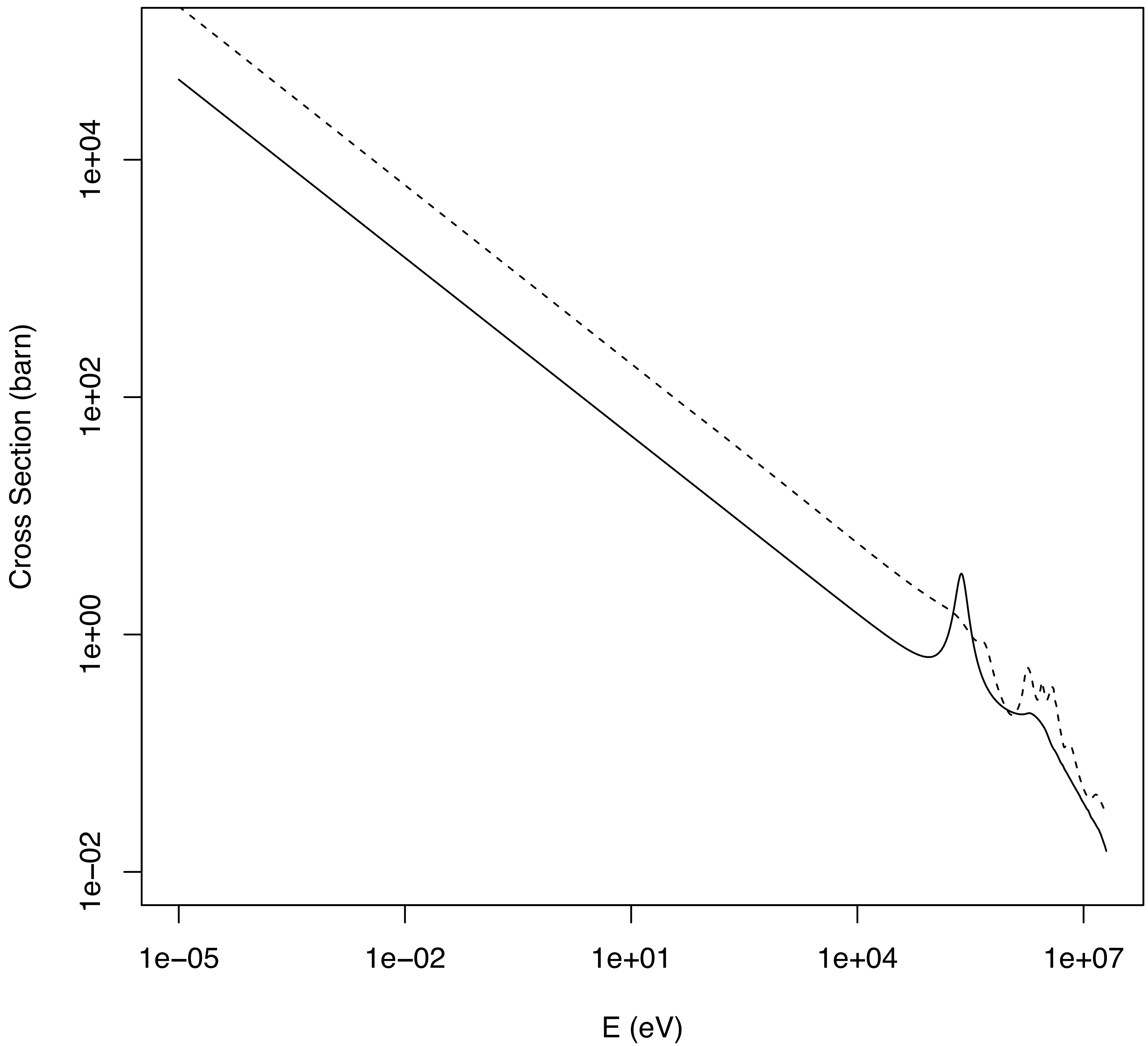
α-SEU: relative estimate C4 bump





Data from a regular solder lot, built in 2003, which led to the ULA process. From multiple devices in the array. Activity of this material in this lot caused one upset ~ 80 days per device.

The ^{10}B problem



Results for ADC qualification

Part Number	Range (bits)	Clock (MHz)	Power (mW)	Manufacturer	Max. Dose (kRad)
AD9265-80	16	80	210	ADI	220
AD9268-80	16	80	190	ADI	160
AD9269-40	16	40	61	ADI	120
AD9268-65	16	65	175	ADI	170
LTC2204	16	40	480	Linear	180
LTC2173-14	14	80	94	Linear	105
LTC2193	16	80	125	Linear	220
ADS6445	14	125	320	TI	210
ADS5263	16	100	280	TI	680
HMCAD1520	14	105	133	Hittite	700

ADS5263 and HMCAD1520 are particularly resistant to total dose. They will be tested for single event effects and possible mitigation techniques developed. All ADCs are manufactured using 180 nm feature size, with the exception of LTC2204 that is manufactured in 350 nm.

Most new COTS can (potentially) sustain substantial total dose.

SEU on the other hand is another issue. Here we need to learn if parts don’t die, and if it is only upset, how to get out of it - how long etc... -> MITIGATION.

Industry already does test parts, e.g. Xilinx, Altera but many of the strategies need to be custom built for HEP

We also need to understand how the way we use components influence on radiation. For example, annealing cycles.

Another important topic is radiation monitoring, especially SEU. Need to have good references when testing, and also running the experiment.

It is a somewhat moving target as technology evolves - here there are many strategies - use pin diode, memories, CCDs, etc.

Plans for immediate future

1. Test COTS, ADCs, Optical Link components and FPGA.

2. Collaborate with people who already have expertise. In some cases collaborate with Industry.

3. Test with Neutrons - Currently scheduled tests at LANSCE.

4. Looking for schedule at Uppsala and CERN.

5. Our baseline has been Mass General (intense beam)

If we want to use $\lesssim$130 nm feature size ICs (non thermal)

	proton	neutron	e and μ	γ
dE/dx	Yes	No	Yes*	No
Threshold for particle prod.	7.9 MeV α	2.75 MeV α	-	~12 Mev p
Space Environment	Yes	No	No	No
Terrestrial Environment	No	Yes	Yes	~Few
Flux at Electronics	<0.001 kHz/cm²	1 kHz / cm²	0.1 kHz / cm²	1 kHz / cm²